Scavenging of oxygen from $SrTiO_3$ during oxide thin film deposition and 2DEG at oxide interfaces

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The discovery of a 2DEG at the interface between epitaxial $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) over a decade ago has led to a flurry of research activity exploring the nature and origin of this conductive interface. This 2DEG has sufficient mobility to exhibit SdH oscillations and much work on developing device applications of this system has been published. Experiment and theory show that the 2DEG at the oxide/oxide interface has many exotic features. It can be paramagnetic, ferromagnetic or even superconducting, with strong Rashba splitting leading to a controllable magnetic moment One explanation involving oxygen vacancies is used for 2DEGs arising in several related interfaces such as amorphous LAO on STO and γ-Al_2O_3 on STO. In the vast majority of 2DEGs reported to form at oxide interfaces, the substrate has been TiO_2-terminated STO with only a handful of exceptions. Potential chemical reactions between the arriving metal species during oxide thin film deposition and the substrate have been largely ignored in these explanations for the 2DEG formation although this has recently begun to change. There is growing evidence that many metals steal oxygen from STO even in the presence of relatively high oxygen pressures.

To better understand the effect of metal oxide deposition on a STO surface, we examine the effect of depositing various metals layer by layer on STO in terms of the evolution of the electronic structure and oxidation state of the metal overlayer. We show that the deposition of metals that have a high oxygen affinity on STO, even under an oxygen-rich atmosphere such as in oxide thin film deposition, typically leads to an interfacial layer of oxygen-deficient STO. We analyze the electronic and chemical evolution of metals deposited on STO using in situ XPS and classify metals into three regimes depending on their oxide formation energy and work function. We demonstrate how redox reactions with STO of metals belonging to one of these regimes can be used to produce interfacial 2DEGs that are quite similar to the crystalline LAO on STO system, and that an oxygen-deficient STO layer could even explain the 2DEG in that system.

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